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In the World of Isotopes

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1. ON THE THRESHOLD OF A NEW ERA

Many scientific discoveries make their way into everyday life gradually and unnoticed. It wasn't so long ago that the researches of scientists in atomic physics seemed far removed from practical life. But it was precisely here that science harnessed the most powerful force of nature and opened up vast potentialities for perfecting the whole pattern of present-day technology.

Scientists made their first acquaintance with atomic energy at the turn of the century when special, radioactive, substances were discovered. The atomic nuclei of these substances disintegrate spontaneously, releasing a very large quantity of energy. But the energy of radioactive decay is given up in small portions over a long period of time, and there is no way to accelerate the process.

Science was confronted by a tempting problem, that of finding a way to harness the colossal energy stored up in the atomic nucleus. And physicists solved it.

The discovery of ways to obtain atomic energy is not the invention of any one scientist or of the scientists of any one country. Success was achieved after years of studying the atom and its nucleus in many countries. Soviet scientists also made a significant contribution to this big and noble end.

Atomic energy is now "liberated" in so-called "atomic piles" or nuclear reactors. In these plants energy is re-

leased, during the fission of atomic nuclei, in the form of heat which may be used for different purposes, one of which is to move a steam or gas turbine that rotates an electric generator, thus converting atomic energy into electricity.

Yet another peace application of atomic energy has to do with the radiations of radioactive substances. Radioactive substances, or, to use the more common term, radioactive isotopes, belong to the "non-energy" field of atomic engineering which is beginning to find a broad and diverse application in industry, agriculture, medicine and scientific research.

Radioactive radiations have great penetrating power which is something that offers extremely intriguing possibilities. The invisible radiations of radioactive isotopes are becoming a means for control and automation in industry; they act as catalysts in chemical processes, and are a powerful factor in biology and medicine. Finally, these same radiations may be used for making small-size, long-lived sources of electric current.

The radioelements open up one more remarkable possibility. They enable scientists to follow the movement of invisible particles of matter, to see the paths taken by individual atoms and molecules, to distinguish individual atoms of a chemical element from other atoms of the same element. No matter where the radioactive atoms are, they reveal their hiding place by radiation. This property or "label" enables us to detect them anywhere.

Special instruments called counters are used to detect such "tagged" atoms. In this way it is possible to count the number of radioactive atoms that, for example, enter an organism. Also, the radiation of tracer atoms affects a photographic plate much as the rays of visible light do. Such atoms make their presence known by "signing" on the plate.

Besides, in all kinds of chemical transformations the radioactive isotopes of an element behave the same way

as their non-radioactive brothers do. By observing how the radioactive atoms "travel" during chemical reactions, scientists determine the behaviour of the atoms of different substances. Tracer atoms enable us to "look into" the processes and follow the doings of chemical elements in all sorts of materials.

The tracer method is gaining recognition in the most diverse fields of life. Tracer atoms have become one of the branches of atomic engineering and are a remarkable instrument of investigation wherever the problem is to detect a substance or to study the processes of its transformation and motion.

In 1907, Marie Curie Sklodowska, who discovered the natural radioactive elements of radium and polonium, made a present of one gramme of radium to the Paris Institute. At that time this was an exceedingly valuable gift, costing several hundreds of thousands of rubles. Plants processing ores that contained radioactive substances did not obtain more than several grammes of radium a year. It is obvious that at that time there could be no question of utilizing the atomic energy of radioactive substances on a large scale.

Now, radioactive isotopes are obtained artificially, mostly in nuclear reactors, these "alchemistic" furnaces of our age. They are obtained as by-products in the production of atomic energy and in such quantities as were only dreamed of twenty years ago.

A real possibility appeared for applying the energy of radioactive substances wherever it is needed. Radioactive atoms are beginning a new life as man's best helpers.

2. "FACTORIES OF RADIOISOTOPES"

The centuries-long attempts of alchemists to transform one element into another ended in failure. What the alchemists of the Middle Ages were not able to do, was accomplished by the physicists of the 20th century.

It turned out that radioactive decay accomplishes exactly what the "makers of gold" had at one time attempted, the transmutation of one element into another. And this is not surprising since, roughly speaking, chemical elements differ from each other as to the magnitude of electric charge of the atomic nucleus. By way of illustration, the atoms of mercury differ from those of gold only in one respect: in gold the charge of the nucleus is one elementary unit less than that of the atomic nucleus of mercury. It is sufficient to change the charge of the nucleus of the atoms of a chemical element for it to become another element. These are precisely the changes that take place in the natural disintegration of radioactive elements.

When radioactive substances decay the atomic nuclei emit three main types of rays. One type, alpha rays, consists of a flow of particles with a positive electric charge. The second group of radioactive rays is a stream of fast electrons that carry a negative electric charge. These are called beta rays.* The third type of radiation, gamma rays, is very much like X-rays. Thus, if alpha or beta rays are ejected from a nucleus, its charge changes and the nucleus of one element is then converted into the nucleus of another.

The question naturally arises: is it not possible to produce this transformation artificially? The answer is yes. Scientists now find no difficulty in transforming one element into another. Gold may be obtained from mercury just as was dreamed of by the alchemists of the Middle Ages. However, such gold costs much more than that extracted in gold mines.

In 1934, two well-known French physicists, Irene and Frédéric Joliot-Curie, obtained artificial radioactive atoms (isotopes) of such ordinary stable elements as nitrogen,

* In decaying, certain artificially obtained radioisotopes eject not electrons, but positively charged elementary particles, so-called positrons.

phosphorus and others by "bombarding" various substances with beams of microparticles.

Since that time scientists have studied hundreds of different nuclear transformations which give birth to "chemical twins," or isotopes. Chemically their properties are the same, the only difference is that, unlike their stable brothers, they are radioactive.

Many hundreds of different radioactive isotopes have been obtained in this way. But even these radioactive substances were very expensive before the atomic pile became a component part of atomic engineering. Though the primary purpose of the pile is to produce atomic energy, it has at the same time become a "factory of radioactive isotopes," where the latter may be produced in large quantities. Gold, copper, iron and phosphorus placed in a nuclear reactor come out radioactive.

Let us examine one of these unusual "factories" of radioactive substances.

A two-hour ride from Moscow will take you to the town of Maloyaroslavets. Near by, surrounded by forests, is the first Soviet atomic power station. The main three-story building of the station bears a certain resemblance to a school. Only a high chimney mars the effect. But no smoke emerges from the chimney. The impression one gets at first is that the station is not working. Everything is quiet. But this is not so, the station is working and is producing electricity.

The station is housed in three buildings. The atomic pile of the station is a reactor with a graphite moderator. The main building contains the heart of the nuclear power station—the reactor together with the control board, the heat exchangers, pumps and other equipment connected with the reactor or used for scientific research. In the second building is the steam turbine and electric generator, and also electric and other apparatus and equipment. The third building houses the ventilation system that keeps

the rooms clear of dangerous radioactive gases produced by the reactor.

In this case, the nuclear reactor plays the part of the steam boiler in conventional steam power stations. It contains the "atomic fuel" or, as it is usually called, the "nuclear fuel," which at present is chiefly the heavy silverish metal uranium. When the fuel "burns," the atomic nuclei of uranium are split into fragments. The process continues without interruption. This "burning" of nuclear fuel in the atomic pile can be controlled—accelerated or retarded.

The heat generated in the reactor raises the temperature of the water circulating in the pipes that pass through the core of the pile. The water transfers the heat from the reactor to the steam generators, producing live steam which in its turn rotates the power generator. This, in general outline, is how the station works.

When in operation, the nuclear reactor produces streams of radioactive radiations (gamma rays and elementary particles called neutrons). During the fission of atomic-fuel nuclei, neutrons are released in huge quantities. Nearly 60,000,000 million neutrons pass through a cross section of one square centimetre every second in the pile.

Radioradiations are dangerous to human beings. For this reason, atomic piles have a massive protective shield made of materials such as concrete, special grades of steel, lead, water, etc., that stop radiations.

In addition to this, the nuclear reactor of the first Soviet atomic power station is enclosed in a hermetically sealed steel cylinder. Outside, it is surrounded by a metre-thick layer of water and a concrete wall three metres in thickness. On top there is also a steel cover and a thick plate of cast iron. All of this provides for the maintenance personnel of the station sufficient protection from harmful reactor radiations.

Artificial radioactive substances are usually produced in the following way. The protective shielding of the atomic reactor has special channels into which chemical elements are inserted at varying depths. When the reactor is in operation these elements are subjected to a powerful "bombardment" by neutrons flying out of the pile and become radioactive. Cobalt becomes radiocobalt, nitrogen is converted into radiocarbon, chlorine is transformed into a radioactive isotope of sulphur, etc. In this way, it is possible to obtain large numbers of artificial radioactive isotopes of different elements in Mendeleyev's Periodic Table.

At present, there are over 1,000 radioactive isotopes (both natural and artificial), which have different half-lives, different radiation and different energies. Radioisotopes which are easily produced and which have half-lives that are not too short are finding extensive application.

The majority of the more important radioisotopes are obtained in the reactor as described above. However, there is also another way. During the operation of a nuclear reactor a peculiar "ash" accumulates. This is "unburnt nuclear fuel" and is very valuable. Artificial radioactive isotopes of certain elements are produced as a result of the fission of uranium nuclei; among them we find, for example, the valuable radioisotopes of cesium and europium, which are being used in many ways.

It must be added that artificial radioactive isotopes may also be obtained in so-called accelerators, which are machines that produce powerful beams of alpha particles, protons, deuterons (the nuclei of heavy hydrogen atoms) and neutrons. Artificial radioisotopes may be obtained by using these particles to "bombard" different elements of the Periodic Table. One of the most widespread machines of this type is the cyclotron. However, the chief supplier of artificial radioactive isotopes is the nuclear reactor.

3. "RADIOEYES"

Radioactive atoms open up great possibilities for control and automation of production processes.

X-rays and the magnetic method have been used for a rather long time to detect internal flaws in metal parts. However, these methods cannot be used to inspect very thick parts since X-rays cannot penetrate more than two or three centimetres of metal. And besides, the equipment is cumbersome and expensive.

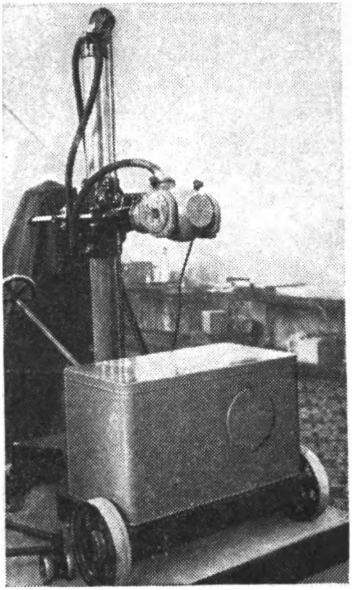
Now, a radioactive isotope of cobalt (cobalt-60) and also certain other radioelements are being used to inspect the quality of steel. Cobalt-60 can "see" through 30 and more centimetres of metal.

Here is the way it is done. The part to be examined is placed between the source of radioradiation and a photographic film. The gamma rays pass through the metal and are absorbed to a less extent in places where there are cavities and cracks. This leaves a trace on the film. In this way, invisible cracks in machines or pits in metal billets are easily detected, and the quality of welded seams may be determined. This is the gamma-ray test method. The inspection of parts by this method is much more rapid and accurate, and, what is most important, it can be done directly in the factory since the required apparatus is relatively simple.

Gamma-ray test techniques are used in our industry. The State Inspection of the U.S.S.R. requires that all welded boilers, bridges, ship hulls, gas pipelines, etc., be tested with radioactive isotopes. The Soviet Union is building thousands of kilometres of new gas pipelines, and every line will pass through the strict and cheap "atom control."

A radioactive level gauge for liquids in closed vessels is used to measure the level of molten steel during continuous casting. The principle of control here is very simple. A source of radioactive radiation is placed on one

side of the crystallizer, on the other side of which is a counter. Radioactive radiation passes through the walls of the crystallizer and is detected by the counter. But all of a sudden the counter stops. This means that the liquid metal in the crystallizer has blocked the rays coming from the radioactive source.

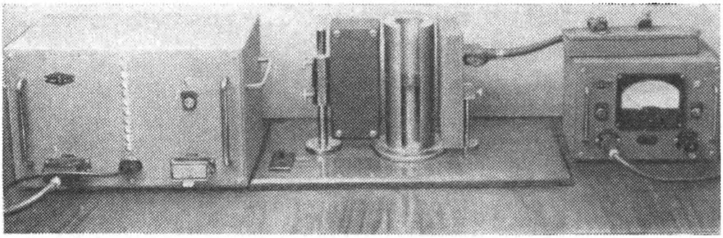


Industrial gamma-ray unit for testing metals

In the same way it is possible to determine the level of molten iron in cupola furnaces. In power stations, the "radioeye" follows the water-level in the steam boilers. Radioactive level gauges are widely used in Soviet factories.

Radioactive radiation makes possible the automatic control of the thickness of materials in the process of production. One of these methods of control consists in the following: gamma rays (or beta rays) are sent through a strip of metal, rubber or paper during its manufacture. The thicker the strip the greater the absorption of radioactive radiations. The gamma radiation that passes through the strip is measured by a counter. If it is connected to an automatic device, it is possible to maintain one and the same thickness of the strip during production. In this way the thickness of parts may be measured and adjusted without interrupting the production process.

Radioactive thickness gauges are in use in Soviet factories, for example at the Leningrad Metal Works,



Liquid-metal level regulator

in the rolling mills of the Magnitogorsk Iron and Steel Works and elsewhere.

The use of radioactive thickness gauges in rolling mills helps to raise both their efficiency and the quality of the goods. For example, when rolling tin plate it is important to maintain a very definite thickness. Even a slight deviation from the required dimensions produces defective goods. The thickness of the steel strip must be under constant control. Formerly, this was done by hand using a micrometer. But the metal strip is drawn at a high speed. So when the roller measured the thickness of the tin he had to slow up the rolls, and this meant a cut in the efficiency.

Now, with radioactive isotopes, control has become much more simple and accurate. The bright strip of metal speeds into the rolls without waiting so much as a second, and all the while the atom controllers are vigilantly checking the quality. The instrument needle keeps the roller constantly posted on the thickness of the metal.

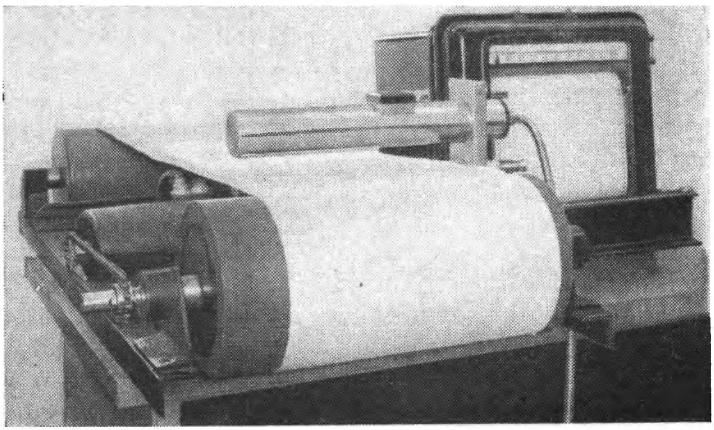
If the surface of a part is irradiated with beta rays, the intensity with which the beta rays are reflected from the surface layer varies with its thickness. This makes possible constant non-contact control of the surface-layer thickness of materials. Research has shown that such control guarantees precise measurements up to a fraction of a micron.

Atomic energy is also used in accident prevention. Let us take a department with high-speed stamping presses. With rapid movements calculated to the fraction of a second, the press operator pushes the blanks under the press and takes out the finished parts.

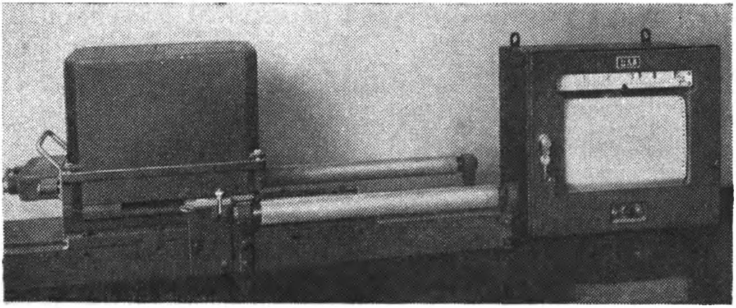
But now watch the operator: he puts in a blank and is late in pulling his hand out of the danger zone. The heavy press falls and— But there is no accident, the press is stopped. The accident was prevented by a small ring on the operator's finger, which contains a radioactive substance.

This is how it works. Above the press is a counter connected with an automatic device that switches the machine on and off. While the operator's hand is under the press and radioactive radiation reaches the counter, the press cannot fall.

An interesting apparatus is now used by Soviet metallurgists to determine the quality of refractory linings inside a blast or open-hearth furnace. During the construction or capital repairs of a furnace, ampoules with



Paper thickness gauge



Thickness gauge for cold-rolled sheet

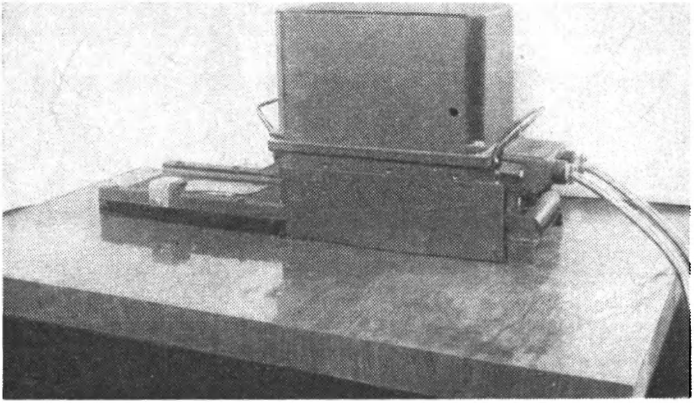
radioactive isotopes that differ as to type of radiation are embedded in the refractory lining at various depths. The refractory brick coming in contact with molten iron and slag gradually deteriorates, and one by one the radioactive ampoules dissolve in the iron. When the iron is tapped the type of radioactivity indicates which of the isotopes have appeared and thus also the amount of wear in the refractory lining of the furnace. This method of control, applied at the "Zaporozhstal" Works, the Kirov Plant and elsewhere, has made it possible to stop the furnaces for repairs at exactly the right time.

In many industrial processes, timely replacement of worn-out parts is very important. Old methods of measuring the wear of parts could not be applied without stopping the machines.

Now, in order to determine when it is time to change a part (for instance, a piston ring in an engine), a small quantity of radioactive substance is placed at a certain depth from the friction surface. As soon as the part has worn down to this permissible limit, radioactive atoms appear in the lubricating oil. It shouldn't even be difficult to have the atoms trigger a signal system which would automatically stop the machine.

Soviet scientists have also developed a precise and quick method of investigating the wear resistance of cut-

The "Zaporozhstal" Steel Works.
A roller watches thickness-gauge indicator



An instrument for determining the thickness of tin coatings on metal

ting tools during operation. Radioactive isotopes permit measuring the amount of wear of a part to within one ten-millionth of a gramme. The new method also enables us to determine quickly the optimum cutting speed.

Investigations with radioactive atoms conducted at the Tractor Research Institute have helped to determine the influence of lubrication, engine power, crankshaft r.p.m., dust, and other factors on the rate of engine wear and to determine how the metal is transferred from one friction surface to another.

In the U.S.S.R. every year sees greater quantities of oil, kerosene, petrol and other liquids transported over tremendous distances by pipe. Formerly, difficulties were met when different types of liquids were pumped through one and the same pipeline. These are now done away with by using radioactive isotopes. When the delivery of one grade of fuel stops, several drums of fuel containing an admixture of a radioactive isotope that emits gamma rays are pumped into the pipeline, after which the new fuel is

pumped in. At the other end of the line is a gamma counter. At a given instant the counter signals that radioactive isotopes have appeared in the fuel, which means that the flow of one grade has stopped and that the new fuel is to be shunted to a different tank.

At the construction sites of hydroelectric stations one can see powerful suction dredgers filling in dams, digging canals and construction pits and doing many other things. Using a special cutter rotated by a powerful electric motor, the dredger breaks up the ground, mixes it with water and pumps the spoil through pipes over distances up to several kilometres, where it may be sluiced into place to form a dam. It is important to know the composition and consistency of the spoil passing through the machine since they affect the efficiency. Up until recently, it was impossible to control the soil content in the spoil. Now a special instrument has been designed that uses radioactive cobalt to indicate continuously the ratio of water and soil in the spoil.

Radioactive control of suction dredgers working at the Kuibyshev Power Station and other hydroelectric stations have helped to raise the efficiency of these machines by 20 per cent.

During recent years, both in the Soviet Union and abroad, radioactive isotopes have been used for marking grades of steel. The simplest method of marking was proposed by workers of the Physics Institute of the Latvian Academy of Sciences, V. A. Yanushkovsky and A. D. Tumulkan. It consists in the following. An electric discharge is used to draw tiny "lines" of a radioactive substance on the metal. The various grades of steel differ from each other by the number of such "lines," which may be easily determined by using a counter.

Of interest is the use of radioisotopes to determine the area of figures. A simple device was built that is capable of measuring the area of the most intricate shape in a matter of seconds. A paper pattern of the shape required is placed

Research workers of the Physics Institute of the Latvian Academy of Sciences determining grade of steel marked with radioactive atoms

on a grid between a source of alpha radiation and an ionization chamber, an instrument that measures the radiation intensity. The chamber is connected with another instrument, the needle of which indicates the area of the figure. If there is nothing between the source of alpha particles and the ionization chamber, the needle rests at zero. But as soon as we place a paper pattern on the grid, the stream of alpha particles and the current produced in the ionization chamber is reduced in proportion to the area of the pattern.

4. RADIOISOTOPES AND GEOLOGICAL PROSPECTING

Radioactive methods are now finding a very important application in prospecting for mineral deposits. Here is how the search for oil is conducted. A radioactive source of fast neutrons and an instrument that measures gamma

radiation are lowered into the test well. The neutrons penetrate into the surrounding rock and are quickly slowed down and captured by the atomic nuclei of the rock. This produces gamma radiation. Different rocks slow down the neutrons to a greater or lesser degree and therefore the intensity of the gamma radiation varies. It has been found that a stream of neutrons is slowed down more rapidly when it passes through layers of rock that contain oil. In this way, it is possible to locate the position of the *oil-bearing layers*.

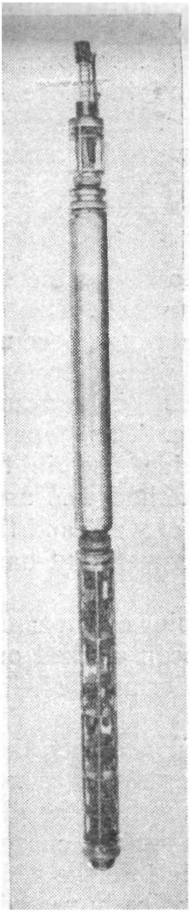
Neutron irradiation can also be used to determine the interface between underground waters and oil. Due to neutron bombardment, the sodium in the water becomes radioactive and produces radiation. And since petroleum contains no sodium, the interface between underground waters and petroleum is clearly definable. This type of radioactive prospecting is already in wide use in the Soviet petroleum industry. In 1954 this method was used to explore three and a half million metres of well, and the result was that many old, abandoned wells were put back into operation.

Gamma radiation may be used to locate coal seams. Such a method for coal prospecting has been worked out by a group of scientists of the Urals branch of the U.S.S.R. Academy of Sciences.

The method used hitherto and based on the fact that rock and coal conduct electric current differently was not sufficiently accurate. The new method is based on the different densities of rock and coal. A device with a charge of radioactive substance is lowered by cable into the well. On the surface is an apparatus that automatically records any variation in the radioactivity of the radiations (gamma rays) that penetrate the rock. The graph made by the device provides data indicating the presence of a coal seam, its thickness and the depth of occurrence. An apparatus for this method of prospecting was tested in the Kizel Coal Basin.

Experiments have shown that the new method cuts twofold the time required to study a well. The gamma rays make a careful "survey" of the rock, through which the well passes, and unerringly find the seam of coal. Radioactive prospecting is now used in many of the country's coal deposit areas.

Terrestrial rocks are known to contain natural radioactive elements such as uranium, thorium and others. In the process of disintegration they produce radiation which is caught and measured by instruments on the surface of the earth or even in airplanes. In this way, mineral deposits containing radioactive elements may be discovered. During the past few years, valuable deposits of tungsten ores have been discovered in the U.S.S.R. by using this method.



Radioactive prospecting for petroleum. Here an apparatus is being lowered into the well

5. TRACER ATOMS IN INDUSTRY

It is no longer an easy task to survey all the possible uses of tracer atoms in industry, and as time goes on their applications in different fields will become still more numerous.

We know that the properties of any metal alloy depend to a great extent on the mutual position of its elements. By using tracer atoms we can get a clear picture of how the atoms of a given element are placed in the alloy. To do this, tracer atoms of one of the component elements, for example of sul-

phur, are introduced into the alloy during its production. If we now place, for a short time, a photographic plate wrapped in black paper on the smooth surface of a piece of the alloy, the developed plate will show the position of the sulphur.

Tracer atoms enable us to study the structure of metals in such detail as cannot be attained by other methods. This is of great importance, for example, in controlling such processes as hardening and tempering, in the study of the welding process, in the production of new types of alloys, etc.

Tracer atoms are finding more and more applications in metallurgical plants because the processes that take place in blast and open-hearth furnaces are extremely complicated.

An important factor for cutting the melting time of the metal in an open-hearth furnace is the acceleration of slag formation (slag is needed to rid the steel of harmful impurities). For this reason, it is important to know in what order the ore and limestone are charged into the furnace so as to produce the speediest formation of liquid slag. This difficult problem is now being solved by radioactive tracer atoms in the following way.

Tracer atoms of calcium, iron and phosphorus (which produce different-type radiations) are introduced into the layers of ore and limestone. Iron is then poured into the furnace and the steel-melting process begins. After the formation of slag has begun, a check is made to determine when and what kind of radioactive atoms appear in it. In this way it is a simple task to determine precisely what part of the ore and limestone (into which the corresponding tracer atoms had been introduced) has already melted.

Such studies have already been conducted in many plants, such as the Magnitogorsk and Kuznetsk Iron and Steel Works, the "Azovstal" Steel Works, the Karl Lieb-

knecht Plant and others. The result is better methods of charging open-hearth furnaces.

Similarly, tracer atoms are used to investigate the rate of movement of the charge in blast furnaces. At the Dzerzhinsky Iron and Steel Works in the Ukraine, investigations of this type served as a basis for compiling instructions that give the most suitable order for charging a blast furnace.

There are cases in production practice when it is difficult to find the source of contamination of the metal. A question like the following confronted the metallurgists of a Soviet plant producing bearing steel in electric furnaces. Calcium had been getting into the steel and no one knew where this harmful impurity came from. Slag was suspected, but how was one to check this?

Tracer atoms came to their aid. Research workers V. A. Grigoryan, E. S. Kalinnikov and A. M. Samarin introduced a radioactive isotope of calcium into the different substances that come into contact with the steel during its production and found the sources of contamination. It appeared that the calcium had got into the steel not from the slag, but mostly from the refractory lining of the ladle. After that, it was not difficult to eradicate the cause of contamination.

Construction work is conducted on a vast scale in the Soviet Union. Scientists are making new building materials that are strong, durable and pleasing to the eye. In this work also tracer atoms are a great help. Very important, for example, is the work devoted to improving the quality of plain and reinforced concrete. Here, Soviet scientists have used tracer atoms of calcium. The invisible "scouts" helped in a detailed investigation of how concrete hardens and what physical and chemical processes take place, thus yielding data of great value.

6. TRACER ATOMS IN CHEMISTRY

Radioactive tracer atoms are now being used in organic and inorganic chemistry to investigate all kinds of processes.

By way of illustration, we may mention the study of chemical processes in the production of rubber. The question of how crude rubber is converted into vulcanized rubber is very complicated and is in many respects still not clear. Chemists do not know the different stages through which this transformation passes. The method of tracer atoms is now being successfully applied to clarify this problem.

Of interest is the use of tracer atoms to determine the percentage content of chemical elements in mixtures, especially if the quantity of the elements is negligible. The radioactive method is capable of detecting a millionth part of one per cent of an element in an alloy or ore!

Thanks to tracer atoms, chemical tests are now being made more rapidly and accurately than formerly. And this is often essential. Take for example the so-called "lightning analysis" of slag for phosphorus now used at the "Azovstal" Steel Works. A radioactive isotope of phosphorus is introduced into the iron before charging the latter into the open-hearth furnace. As the metal melts the phosphorus gradually passes from the iron into the slag. By assaying the slag from time to time for radioactivity (a counter is used for this purpose) it is an easy matter to determine the phosphorus content. This whole procedure (together with the sampling) lasts six or seven minutes.

A new field of science called radiation chemistry that treats of the chemical transformations of a substance caused by radioactive radiations is opening up broad vistas to industry. High-energy nuclear radiations cause profound changes in the structure of complex organic materials, such as rubber. Some materials become insoluble in water,

or cannot be melted, others disintegrate, generating large quantities of gas. In some materials, radioactive irradiation causes molecules to break up, in others, on the contrary, it causes them to coalesce. All this is very important to know when producing artificial materials and substances with pre-set properties.

It is interesting to note that nuclear radiation may be used to produce an exceedingly firm skin on metal. Experiments were conducted with cutting instruments and after irradiation the resistance increased tens of times!

Radioactive radiations are capable of changing the course of very important chemical reactions, such as the process of polymerization when several molecules combine to form one large molecule, called a polymer. In this way, plastics, synthetic rubbers, etc., are produced. It was found that in a number of cases radioactive irradiation accelerates the process of polymerization. It can also help to initiate reactions that are difficult or impossible to produce by other methods. Entirely new polymers may be obtained in this way.

The investigations of scientists in the U.S.S.R and other countries have shown that aniline, which serves as a basis for many dyes and other substances, may be obtained from benzene with the aid of powerful radioradiation.

When two different plastic materials are irradiated they merge into a single whole, making it possible to create protective coatings on goods. This work has not yet gone beyond the investigation stage, and much of what has been obtained experimentally is of no practical value as yet. But there can be no doubt that radiation chemistry will in the near future give man no small number of valuable discoveries.

7. THE GEOLOGICAL CLOCK

In nature there are several radioactive elements, such as uranium, radium, radon, etc. Their decay always proceeds with strict regularity under all conditions: for each element there is a definite time in which one half of the radioactive substance decays no matter what quantities of it are taken. Thus, for example, if we take one kilogramme of uranium, then one half of it (500 grammes) decays in 4,500 million years. Half of the remaining quantity of uranium (250 grammes) decays again in 4,500 million years, etc.

The period of time during which the decay of one half of the radioactive atoms takes place is called its half-life. Different radioactive substances have different half-lives. Thus, for example, the half-life of uranium is 4,500 million years, of radium 1,590 years, of carbon approximately 5,700 years, etc.

Scientists have tried to alter the rate of radioactive decay but in vain. Radioactive substances have been heated to redness, they have been subjected to pressure and to the action of electricity, but still the decay rate is the same. This property of radioactive substances has enabled us to mark off periods of thousands of years in the history of our planet and to determine when different events took place on the earth. This is how it is done.

Radioactive carbon is one of the naturally occurring radioactive substances. It is formed from ordinary nitrogen in the upper strata of the atmosphere under the action of cosmic rays arriving from interstellar space. And the quantity of radiocarbon in the air is always constant. At each instant the same number of new radioactive atoms are formed as decay. The radioactive carbon thus produced combines with oxygen to form radioactive carbon dioxide.

Carbon dioxide is food for plants which use it to build up their cells. The atoms of ordinary carbon enter the

plants and along with them are their unstable brothers, the atoms of radioactive carbon. From the plants they migrate to animal organisms.

One important thing should be noted here. While the plants or animals are alive and eat, the relative content of radioactive carbon atoms in them is constant, new ones coming all the time to replace those that decay. One may, for example, take any plant, and in every gramme of carbon in the cellulose of that plant there will be one and the same number of radioactive atoms, about 50,000 million.

But then the plant or animal dies. The supply of radioactive carbon ceases. And from this instant the "atomic carbon clock" begins to tick: the number of unstable carbon atoms in the dead remains of the organism begins to decrease, and to decrease according to a regular law. In 5,700 years the number of invisible radioactive particles will have become one half as many; in 11,400 years, a fourth; in 17,100 years, an eighth, etc.

Due to this remarkable property, it is possible to determine with a high degree of accuracy the time of death of animals and plants from the content of radioactive carbon in their remains.

This "carbon clock" has proved very helpful to archeologists and historians. The museums of the world house a large number of monuments of the past. The ages of many of them have been determined by different factors only approximately. Now this age may be verified and ascertained with greater accuracy.

A piece of wo[illegible] a boat found in the tomb of an Egyptian [illegible]as believed by archeologists to be of the "age" [illegible]3,750 years. Then physicists took over and determined t[illegible] number of [illegible]oactive atoms per gramme of carbon in t[illegible] ancient pie[illegible] of wood. This was then compared to the [illegible]mber that is [illegible]nd in a freshly cut tree and it was calc[illegible] hat the boat is approximately 3,620 years old.

In the U.S.S.R., this method was recently used to determine the "age" of a mammoth found in the ice of the Taimyr Peninsula. The radioactive atomic "clock" showed that the mammoth had lain in the ice about 12,000 years.

Here is the way such measurements are made. A small piece of the article whose age is to be determined is treated so as to isolate pure carbon. If, for example, it is a piece of wood, it is simply burned. The isolated carbon is placed in a small cylindrical vessel which contains a radiation counter that records the decay of each atomic nucleus of the radioactive substance.

Experiments show that in one gramme of carbon taken from "fresh" samples, for example, green wood or the bones of an animal just killed, there always takes place an average of 12.5 nuclear decays per minute. If, however, the carbon is taken from a sample of ancient origin, the number of such decays is less. The older the object, the fewer the decays.

The home of an ancient man was discovered in a cave in France. Stone implements were found and also the coals of a fire. Scientists decided to use the new method to check the charred branches of the ancient camp-fire. They determined the content of radioactive carbon atoms and stated that our ancestors had lived there approximately 15,500 years ago, after the Great Ice Age; it was precisely then that the fire had burnt in this cave!

When archeologists were unable to determine the age of the remains of an ancient boat found during excavations near Tokyo, Japan, the new method came to their aid. The radioactive atoms of carbon st[illegible]is boat is about 3,000 years old. In the boat were [illegible]eeds of a lotus plant and their age was found to be the sam[illegible]. It is interesting to note that after lying three thousand years they had not lost their capacity to germinate. When placed in favourable conditions, the lotus seeds sprouted.

The "carbon clock" is a help not only to archeologists. Everyone knows what an important role petroleum re-

serves play in the affairs of nations. Geologists frequently find oil where methane forms. One may expect oil where he finds methane. But this gas is formed in the earth in other ways, for example, from decaying plants. But in such places oil does not occur.

The problem is how to distinguish the gas of oil deposits? The answer is given by radioactive carbon atoms. The methane of plant origin always contains a larger proportion of labelled carbon atoms than the methane of deposits of petroleum, which formed ages ago. The radioactive carbon clock indicates unerringly the age of the methane and in this way tells the prospectors where the oil is and where it is not.

Now the question arises as to whether our carbon clock can tell us the time of events that took place, let us say, millions of years ago. Unfortunately, it cannot. The carbon clock is capable of measuring only tens of thousands of years. Its "wind" does not last any longer. The reason is that in 60,000 years the remains of an organism contain only a thousandth part of the radioactive carbon atoms that existed during the lifetime of the animal or plant and to detect this quantity is a difficult matter.

But the atoms of other natural radioactive substances, such as uranium, come to the aid of the carbon atoms. The decay of uranium atoms, as we already know, continues not thousands but thousands of millions of years. The end-products of this decay are helium and lead. Every million years one gramme of natural uranium produces approximately one ten-thousandth part of a gramme of lead. The older a given mineral that contains uranium, the more lead there will be in it. This reminds us of the ordinary sand-glass, in which the sand sifts down from the uppermost compartment into the lower one. If we measure the ratio between the quantity of lead and uranium in a given rock, it will be easy to determine the age of this rock from the moment of its formation.

Such a "uranium clock" is capable of marking off periods in the history of our planet that are measured not in thousands but in millions and thousands of millions of years. Roughly eight million years pass before one gramme of lead forms in one kilogramme of uranium. And it takes 2,000 million years for a quarter of the uranium to become lead. And only after a hundred thousand million years will nearly the total amount of uranium in the earth disintegrate into lead and helium.

What does this uranium atomic clock with its mechanism that depends neither on the will of man nor on the forces of nature tell?

It tells the scientist that the age of the most ancient minerals found in the earth's crust comes to nearly three thousand million years. This means that the earth's crust itself was formed not earlier than 3,000 million years ago. And the earth is still older—it is not less than four to five thousand million years old.

The uranium clock tells us that the oldest rocks of Karelia originated nearly 2,000 million years ago. The mountain ranges of the Urals and Tien Shan arose approximately 200 to 300 million years ago. Still younger are the Alps, the Himalayas and the Caucasian Mountains.

Scientists are trying to improve the radioactive atom clock, to make it more precise. Lately, new methods have been developed for determining the age of rocks. The earth's crust contains large quantities of potassium. It is also radioactive, and decays into a gas called argon. By measuring the potassium and argon contained in minerals, it is possible to determine with greater precision the age of rocks, and the geological eras and periods.

Thus, the natural radioactive atoms serve as scouts of the past and help to draw up an accurate calendar of the events of remote ages.

8. A POCKET ELECTRIC STATION

Radioactive isotopes enable us to obtain electric energy from the energy of radioactive radiation directly. Tiny atomic electric batteries have already been constructed and they have certain advantages over the conventional storage batteries, as we shall soon see.

Among the diverse substances that surround us in nature, there is a big group of so-called semi-conductors, which occupy an intermediate position between conductors of electric current and non-conductors (insulators). These "half" conductors conduct electric current, but do it much worse than metals. Among the semi-conductors are many elements and their compounds, such as silicon, selenium, germanium, phosphorus, boron, arsenic, a large number of metallic oxides, their sulphides, the majority of the minerals, certain alloys, etc.

It wasn't so long ago that these substances were like a treasure hidden in the earth. Their properties were hardly known. However the progress of science during the past two decades has revolutionized our conceptions about these substances. Semi-conductors have come to the forefront of modern technology, forming a new and exceedingly important field of science, the physics of semi-conductors.

It was found that the current mechanism in semi-conductors is entirely different from that in metal conductors. When a metal wire carries current this means that the so-called free electrons (that is, those not bound to the atoms) are moving within the wire in a given direction. Such free electrons are always present in metals. Not so with semi-conductors. Depending upon certain conditions, there may or may not be free electrons in them. For example, at low temperatures there are hardly any at all, and the semi-conductor does not conduct electric current. But if such a substance is heated, free electrons appear and the semi-conductor begins to conduct electricity. Semi-conductors may

be acted upon in the same way by light and radioactive radiation. It is this property that is put to use in atomic electric batteries.

Here is how one such device is built. A thin layer of some radioactive substance, say an isotope of strontium, strontium-90, is deposited on a semi-conductor wafer which, after special treatment, conducts current only in one direction. This isotope is a nuclear reactor "by-product" and gives a stream of beta particles without producing the harmful gamma radiation.

The fast electrons emerging from the radioactive substance dislodge large numbers of new electrons in the semiconductor. This produces a flow of electrons in one direction, or, in other words, an electric current. True, this current is very small. But the atomic cells can be combined into a battery to produce a strong enough current to feed radio sets, telephones and the like.

Atomic cells are very small and very light as compared to ordinary dry cells. And besides they have one very important advantage, durability. Atomic electric batteries can operate without being recharged (that is, without replacing the radioisotope) for decades!

9. THE ATOM IN AGRICULTURE

In the spring of 1954, a local type of cabbage seed was planted at the Gribov Plant-Breeding Station near Moscow. Before planting, these seeds were subjected to radioactive irradiation. Investigators eagerly awaited results. And atomic energy justified their expectations. The heads of cabbage took shape and matured eight to nine days ahead of time. This experiment showed that radioactive substances may also be used to advantage in agriculture.

For a number of years, experiments have been in progress on the fields of the Timiryazev Agricultural Academy and elsewhere to see how radioactive radiation affects

cereal plants, vegetables, berries and fruits. These experiments show that the atomic energy of radioactive decay raises the yield when definite doses are applied. For example, irradiation of maize with radioactive cobalt (in small doses) produced a 15 per cent increase in the quantity of green parts over those plants growing in the same field and not irradiated. Moreover, the irradiated plants grew more ears—four and even five in place of two and three.

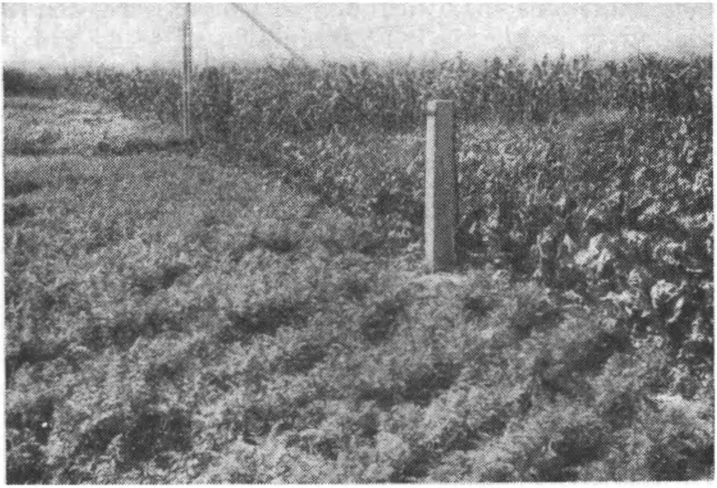
Definite dosages of radioactive radiation accelerate the growth of the plant, its flowering and the maturing of its seeds. In many cases, the same result is obtained if the seeds are irradiated before planting.

Experiments with irradiation of carrot seeds produced a 25 per cent increase in the yield. Irradiation of sugar beets raises the sugar content. During recent years, a large number of experiments have been conducted with the imbibition of seeds in solutions of radioactive substances prior to planting, the aim being to speed up the development of the plants and to increase the yield. This is how our scientists are trying to find ways for the practical application of radioactive substances in agricultural production.

At the present time numerous data have been obtained concerning hereditary changes produced in plants by nuclear radiations. These changes may be of the most varied character. They may develop in the outward structure of the plant, in the structure of its different parts (the leaves, flowers, stem) and also in physiological characteristics, such as early ripening, winter-hardiness, resistance to disease, etc.

Great possibilities open up in the use of radiations in breeding new varieties with useful qualities. For example, plants were obtained that have a very high resistance to fungus infections.

A Soviet scientist, L. P. Breslavets, used the irradiation method to produce a new variety of rye with larger ears.



Field on which L. P. Breslavets conducted her experiments in the irradiation of plants. In the background is a pole with radioactive cobalt

The seeds of this variety are much larger than those of the ordinary plant.

Interesting results were obtained by N. M. Berezina at the Institute of Biophysics of the U.S.S.R. Academy of Sciences. She gave the dry seeds of vetch a powerful dose of radioradiation and produced a new, giant form of this plant. The vegetation period of the new variety is longer, so that green, flowering plants remain on the field up till the frosts.

The effect of radioactive radiations on radishes, peas, carrots, cucumbers, tomatoes and other plants was verified. L. P. Breslavets found that cell division in irradiated plants takes place more rapidly than in the case of non-irradiated plants. This explains the accelerated growth and development of plants.

The above examples are only a small part of the investigations of Soviet scientists in the employment of radio-

active radiations in agriculture. Scientists are also attempting to accelerate the germination of seeds and the growth of young trees in nurseries by using radioactive radiation. They are investigating the influence of the atomic energy of radioactive decay on farm animals, etc.

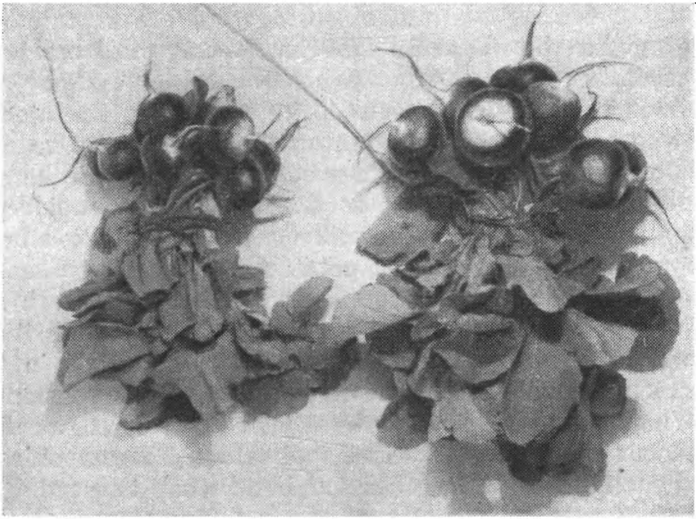
In certain cases, solutions of radioactive substances are used in place of irradiation. The seeds are imbibed in these solutions before planting. This also raises the yields of such crops as sugar beets, winter wheat and maize.

The beneficial influence of radioactive radiations on the yields of agricultural plants may be brought about in yet another way, by putting the radioactive substances right in the soil as microfertilizers. During recent years numerous experiments have been conducted along this line in different parts of the Soviet Union.

Natural radioactive substances, and also shale from deposits in Leningrad Region, which contains small quantities of natural radioactive elements, have been used as radioactive microfertilizers. Experiments showed that such microfertilizers produce big increases in crop yields. In some cases, the crop was double the usual level. They are especially beneficial to barley, buckwheat and many vegetables and technical crops. And they improve fruit-bearing in the case of apples and grapes. Radioactive microfertilizers have been tested on the fields of many state and collective farms, and everywhere the results are good.

There are still other ways of using radioactive elements to raise crop yields. But there are still a number of objections to their being put into practice on a big scale. It is not quite clear, for instance, how dangerous different radioactive substances are to man and animals when they are introduced into seeds and the soil.

On the one hand, it is known that such substances can cause serious illness if they get into a living organism. For this, however, considerable doses of irradiation are necessary. On the other hand, we know that radioactive



Non-irradiated (left) and irradiated radish

substances are always present in nature and that small doses of radioactive radiations are not harmful to human beings. There is no harm whatsoever to man or animals in the external irradiation of seeds and plants. It is precisely for this reason that these methods are being introduced into agricultural practice.

Radioactive irradiation is also used to fight grain pests. For example, the Institute of Biophysics has offered a method to protect grain from weevils. A slight radioactive irradiation quickly stops the spreading of this pest and makes beetles incapable of reproduction.

Anyone knows how hard it is to keep potatoes and many other vegetables in storage till summer without sprouting. When potatoes sprout they lose their tastiness. The amount of vitamin C and starch in them diminishes. How is it possible to prevent this? For hundreds of years there has existed one method: potatoes are not allowed to

feel the coming warmth of spring and are kept in cold storage in the dark. But this method is far from being perfect.

Atomic energy enables us to improve long-time storage of vegetables and to prevent spoiling. This may be done as follows. After the potatoes have been put into storage, small aluminium tubes, or ampoules, with radioactive cobalt are placed there. Small doses of irradiation bring about the required results: potatoes may easily be kept in storage several years and they will always be fresh and juicy. And this irradiation does not affect their nutritious properties. Vegetables that have been irradiated in this fashion are not killed. Life in them is simply dormant.

This method has already been tested by Soviet scientists and is now finding practical application. The ampoules of radioactive cobalt are cheap and they may be used (that is, they produce radiations) many years at a time. For this same purpose special mobile units are being designed that permit irradiation of potatoes in strictly regulated doses when filling the storage bins.

A few words might be added here on the sterilization of food. This is usually done by heating. In the canning industry, for example, sterilization is brought about through the use of high pressure and hot steam. Radioactive radiations make possible cold and rapid sterilization of food. This process is accomplished almost instantly in the flux of atomic energy radiated by the radioactive atoms. Several seconds is all that is necessary to obtain sterile meat, fish or vegetables.

But then the question arises, is not such food detrimental to the health? Scientists made tests on animals by feeding them for a long time with irradiated food. No deleterious effects on their organism were observed. At present this problem is undergoing a thorough investigation. We should expect that in the very nearest future radioactive sterilization of food will be extensively used in our daily life.

Speaking of the use of radioactive isotopes in agricultural science, mention should be made of tracer atoms. This method has produced especially valuable results.

Everyone knows about the importance of increasing yields through the use of scientifically organized fertilization of the soil. The questions that arise are: When and in what cases will the applied fertilizer be best utilized by the plants? What fertilizers are most suitable for wheat, potatoes, maize?...

Formerly it was not an easy task to find answers to such questions. It wasn't clear, for example, how best to apply granulated phosphoric fertilizer, to lay it in rows or to spread it over the whole area and to what depth in the soil, etc. Tracer atoms found the answer to this question quickly and accurately: granules of phosphoric fertilizer should be laid in rows together with the seeds; in this case, small quantities of fertilizer boost yields considerably.

How do the tracer atoms do this?

First of all, the phosphoric fertilizer is prepared with tracer atoms. This is done by adding a small quantity of labelled atoms of phosphorus to the superphosphate in an even mixture. Then the labelled fertilizer is applied to an experimental plot where an agricultural plant, say flax, has been planted. In order to determine the best depth for applying the superphosphate when fertilizing flax, the labelled fertilizer is placed at various depths and at different points, and then observations are made to detect the first appearance of phosphorus tracer atoms in the leaves of the plant. This may be done with a small portable counter of radioactive radiations.

The tracer atoms will not enter the plant until its roots come in contact with the fertilizer, and a counter put against the leaves will not detect any radioactive radiation. But at last the roots of the plant reach the labelled fertilizer. The superphosphate, and with it the tracer atoms of phosphorus, begin to enter the plant. If a counter is now

placed close to the leaves it will immediately detect the presence of the invisible tracers. In this way it is possible to follow with great accuracy the ways and conditions in which fertilizers are best utilized by plants.

Tracer atoms have shown that spraying fruit trees with a solution of phosphate does not produce good results. A better method is to put the fertilizer into holes at a depth of 30 to 35 centimetres.

This new method of scientific investigation showed that for cotton plants the fertilizer should be introduced together with the seeds and that maize and clover assimilate better when the fertilizer is placed in holes than when it is spread over the whole field.

These invisible tracers were used to find out how much phosphorus a plant takes from the soil and how much from fertilizers. Experiments with wheat showed that during the first two or three weeks almost the entire quantity of phosphorus needed for growth is taken out of the fertilizer. Then the quantity of phosphorus taken from the soil begins to increase. By the end of the second month, the plant is feeding chiefly on soil phosphorus.

Maize behaves in the same way. This means that it is best to give wheat and maize superphosphate only during the initial stages of their development. In contrast to wheat and maize, potatoes assimilate fertilizer both at the beginning of the growing period and later on.

A so-called method of non-root plant fertilization has been known. But until recently scientists and farmers did not know to what extent a plant assimilates fertilizer deposited on the surface of the leaves in the form of a solution. Radioactive atoms helped to solve this important problem. It turned out that this method of fertilizing plants is in many cases much more effective than introducing fertilizer directly into the soil. Thus, for example, in experiments with cotton it was found that during the formation of the buds it is much better to spray the leaves with fertilizer than to put the phosphorus into the

soil. Radioactive phosphorus sprayed onto the leaves was found already several hours later in other unsprayed leaves and in the stem and roots of the plant.

At present, non-root fertilization of plants is spreading rapidly. Tracer atoms are helping to find the best methods of fertilization in each concrete case.

Our radioactive scouts made us reconsider another view. It was thought that the saccharine substance in sugar beets is formed in the roots. In actuality, however, the "saccharose factory" is the leaves of the plant and not the roots, which serve only as a "storehouse of finished goods."

Radioactive atoms helped to explain yet another important circumstance connected with fertilizers, namely, how does fertilizer behave in the soil during rain or watering? Does it run off with the ground waters? Tracer atoms again gave the answer. It was found that in sandy loam soils rains do not materially affect the distribution of phosphate. But if the soil is loosened the phosphorus is more easily washed away by rain. If the soil contains considerable quantities of the salts of iron and aluminium, phosphorus combines with them to form compounds that do not dissolve in water.

Another very important result obtained by the method of tracer atoms is the explanation of many details of plant life. As we know, plants absorb water and assimilate nutritious matter from the soil through the roots. Therefore, biologists considered the roots, on the whole, only as intermediaries between the leaves and the soil. The formation of organic substances in a plant (photosynthesis) takes place only in the leaves, whence they are carried to all parts of the plant. It was believed that the carbon dioxide required for this process entered the leaves of the plant only from the air.

Tracer atoms changed these views. Soviet scientists, Academician A. L. Kursanov, Professor A. M. Kuzin and others, used the tracer-atom method and found that the

roots of a plant take carbon dioxide from the soil and convey it to the stem and leaves where it is assimilated. This process proceeds so rapidly that only a few minutes after the carbon dioxide containing radioactive carbon has entered the roots radioactive radiation is detected in the leaves of the plant.

This is a fact of no small practical importance. Now, when looking for the best methods of root feeding one must keep in mind that a plant obtains its carbon dioxide both through the leaves and through the roots. This opens up new avenues of approach to the problem of increasing yields.

Tracer atoms opened to researchers the whole complex picture of the cycle of matter in plants. It was found that in this cycle the leading role is played by the roots and not by the leaves. It is precisely in the roots that the substances which form in the body of the plant during photosynthesis undergo various transformations. Thus, the roots appear to control metabolism in the plant.

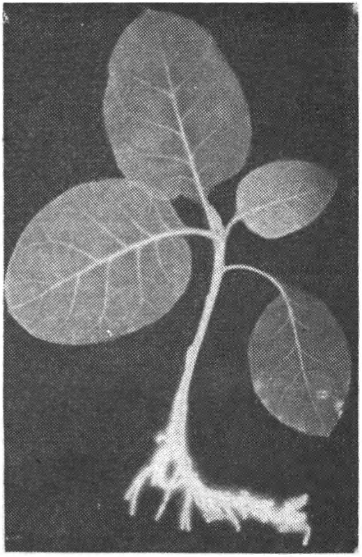
This new method was used to determine the speed with which the different nutrients move in plant organisms. It was found, for example, that water in certain trees covers a distance of up to 14 metres in one hour. Nutritious matter moves from the roots to the leaves at a speed of two to four metres an hour.

A study of metabolism in domestic animals is also of great importance. Here too, radioactive atoms are invaluable to the researcher. With their aid, one may almost visually follow the assimilation of food by the organism and note the speed with which nutritious matter enters the blood stream and the different organs. This speeds up our search for ways of increasing the productivity of the stock.

In such studies, the animal is fed with food that contains tracer atoms of some element. The radioactive atoms enter the organism and immediately reveal themselves by radiation. Using a counter it is not difficult to determine

into what organ or part of the body of the animal the tracer atoms have gone.

By thus following the movement of food in the organism, scientists found that the nutrients taken in with the food are first of all used to build tissue, and the substances that formerly made up the tissue disintegrate, giving the organism its needed energy. Thus, the old conception, according to which the substances that build tissue remain in the organism a long time, was disproved. Tracer atoms, for example, have shown that in eight days one half of the protein of the liver is renewed by food consumed by the organism. The muscles and fats are also rebuilt. Even our bones do not remain unchanged. It was found that radioactive atoms of phosphorus taken in with food go principally to the bones. Thus, phosphorus, which is a necessary constituent of our skeleton, is constantly being replaced in the bones. This discovery forced animal breeders to make a new approach to the problem of food for livestock.



Radioactive carbon absorbed from the ground by the roots of a plant is soon detected in the leaves

Every housewife knows that chickens must be fed with food that contains plenty of calcium so that they can produce the shells of their eggs. It was believed that the calcium in the food went directly to form the egg shell. Tracer atoms disproved this conception. The egg shell is built from the bones of the chicken. In the course of two months

the skeleton of a laying hen is almost completely replaced!

Tracer atoms were also able to tell what nutrients are most readily assimilated in the organism. One such substance is sugar. When an animal was given a solution of radioactive sugar which contained tracer atoms of carbon, within a few minutes the counter found radioactive carbon dioxide in the exhaled air! This means that within a very short time the sugar enters the tissue of the organism and is assimilated, because carbon dioxide is the product of its oxidation. Salt also moves rapidly in animal organisms.

Tracer atoms are very helpful in studying the part played by microelements in the life of animals and plants. Microelements are chemical elements, which though present in the organism in minute quantities, play an essential role in its development. They include copper, boron, cobalt, zinc, lead, iodine and others. A deficiency of them in the food of the plant or animal frequently leads to disease. For example, a deficiency of cobalt disrupts metabolism in sheep, goats and cows, causing a disease called tabes. A deficiency of boron in the soil produces a sharp decline in the yields of such crops as clover and certain vegetables.

Soviet scientists are now engaged in extensive investigations to determine the behaviour of various microelements in living organisms. And here again their faithful helpers are radioactive atoms.

Everyone knows how much damage pests can do to crops. Crop losses throughout the world due to pests could feed many tens of millions of people annually. In the development of different ways of fighting pests science applies once more to radioactive substances. Biologists have learned to put a radioactive "label" on the agents and carriers of disease—spores, insects, viruses, and bacteria. It is very easy to follow such bodies because they are always revealing themselves by radiation.

Using this method, it is possible, for example, to follow the movements of different parasites inside the organism, to see the movements of the pest larvae in the soil, to find out how quickly and how far the carrier insects of a disease move, etc. Soviet scientists have even labelled the viruses of brucellosis. Tracer atoms are now also being pit against pests.

Every day brings more and more facts of progress in the use of tracer atoms. They are finding application in apiculture, in the fishing industry, and in the breeding of new and better varieties of plants, and also in many other branches of agriculture. They help agricultural workers to find sure and rapid ways of obtaining high, stable yields, and of raising the productivity of livestock.

10. THE ATOM IN MEDICINE

Treatment with radioactive radiations is not new. Radium has been used for a long time to irradiate malignant tumours. But it is very expensive. Now a big change has taken place. The fight against malignant tumours is carried on in many hundreds of clinics throughout the country with relatively inexpensive radioactive cobalt, whose healing properties in some cases are even better than those of radium.

Soviet scientists have constructed a special radiocobalt apparatus called GUT-400 which is a therapeutic gamma unit that is now used by thousands of scientists and physicians. The charge of radioactive cobalt in one such unit is equivalent to 400 grammes of radium. To get an idea of what this means let us recall that twenty years ago only in very special and important cases could we get a gramme or two of radium.

The GUT-400 unit is a heavy apparatus, the main part of which is a six-hundred-kilogramme lead ball with a short bent arm. The lead ball contains, deep within it and well protected, an ampoule of radioactive cobalt.

The cobalt unit is operated from a room separated from the apparatus by a thick wall of concrete. When the word "storage" flashes on in green, this means that the ampoule of cobalt is in the centre of the lead ball. When a patient is prepared for treatment and the arm of the apparatus is directed to the diseased spot the cobalt slides down into the arm and a red light flashes on at the control panel indicating that irradiation has begun.

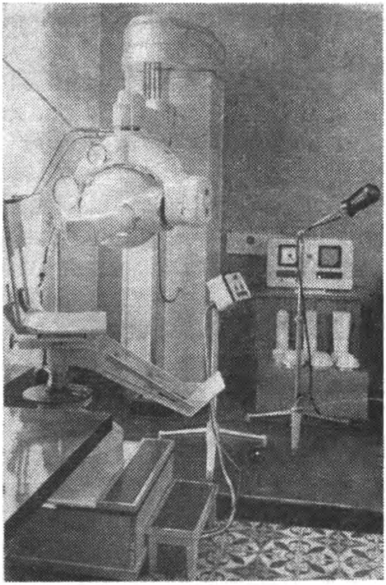
Radioactive cobalt is not only cheaper and more easily obtainable than radium. Its physical properties are more suited to medical purposes than those of radium. The gamma rays of this isotope are more uniform in their energy, and the beta rays are more easily absorbed by the tissue of the organism than those of radium. The result is that cobalt treatment is more effective and produces fewer complications than radium treatment.

Radiocobalt has already saved thousands of lives. The isotopes of cobalt and tantalum are now being used to treat certain eye tumours. Formerly, the life of the patient was saved by having his eye removed. This can now be avoided. Irradiation saves the eye and the sight also.

Medicine also makes use of other radioisotopes such as gold, phosphorus, iodine and sodium. For example, radiophosphorus and radiostrontium have been successful in the treatment of certain diseases of the skin and blood. When these substances disintegrate they emit only beta rays which are absorbed by the skin. For this reason, they are very well suited to the treatment of surface diseases of the skin. This is done by preparing plastic plates that contain a radioactive isotope, or, through a still simpler process, by soaking a cotton cloth in a radioactive solution. The cloth is then dried and is wrapped in a thin layer of cellophane or rubber and applied to the affected spot. This method has been very effective in the treatment of precancerous and cancerous diseases of the skin and other diseases.

A disease is known that causes a sharp increase in the number of red blood corpuscles and in the total amount of blood. The patient suffers from polyemia. The illness develops slowly but if not treated it progresses.

A proper dose of radioactive phosphorus introduced into the organism will inhibit the formation of new red blood corpuscles. Sometimes radiophosphorus treatment is combined with bleeding.



An apparatus designed for irradiation of malignant tumours

The use of radiation from artificial radioactive substances in medicine is a new thing still in the developmental stage. But we may already safely say that the achievements of nuclear physics have put into the hands of the physician a powerful weapon in the fight for human life.

Scientists are constantly at work trying to improve this method. The radiobiological laboratory of the Institute of Biophysics has developed a surgical method using radioactive radiation. The "ray knife," as it is called, is a directed beam of invisible radiations that is capable of destroying a brain tumour without touching the skull and without leaving wounds or scars. In 1956 this "knife" was used in a large number of important studies on animals.

Tracer atoms are now playing a very important part in medicine. The All-Union Industrial Exhibition in Moscow demonstrates an interesting universal radiograph capable

of ascertaining the speed of blood circulation in an organism, the rate at which various substances are assimilated in the stomach and the intestines. It can also indicate where the different substances that enter the organism accumulate. The tracer atom in this case is usually radioactive sodium.

In treating hypertension, drugs are needed that are capable of widening the blood vessels, thus creating freer circulation of the blood. But how to find such drugs? A hypertensive patient is asked to breathe a mixture of air and the radioactive atoms of xenon, a rare gas. The labelled xenon atoms enter the lungs and then the blood stream and are sent to all parts of the body. Using a counter, the physician can determine the time required for the blood to circulate from the lungs to the extremities. The patient then takes a medicine and in a little while the physician again checks the speed of the xenon atoms as they travel about the organism. If they now cover the distance from the lungs to the extremities in a shorter time, this means that the blood is circulating faster and the medicine has been effective.

New drugs are constantly being introduced into medical practice. But before they can be used, they must be tested on animals; the effect on different organs and of different quantities and the rate at which they are excreted from the organism must be studied.

These investigations are now carried out with ease. The medicine is labelled and its movements, assimilation and accumulation in the organism are observed.

Tracer atoms have enabled physicians to locate the affected parts of internal organs and to look into the human organism.

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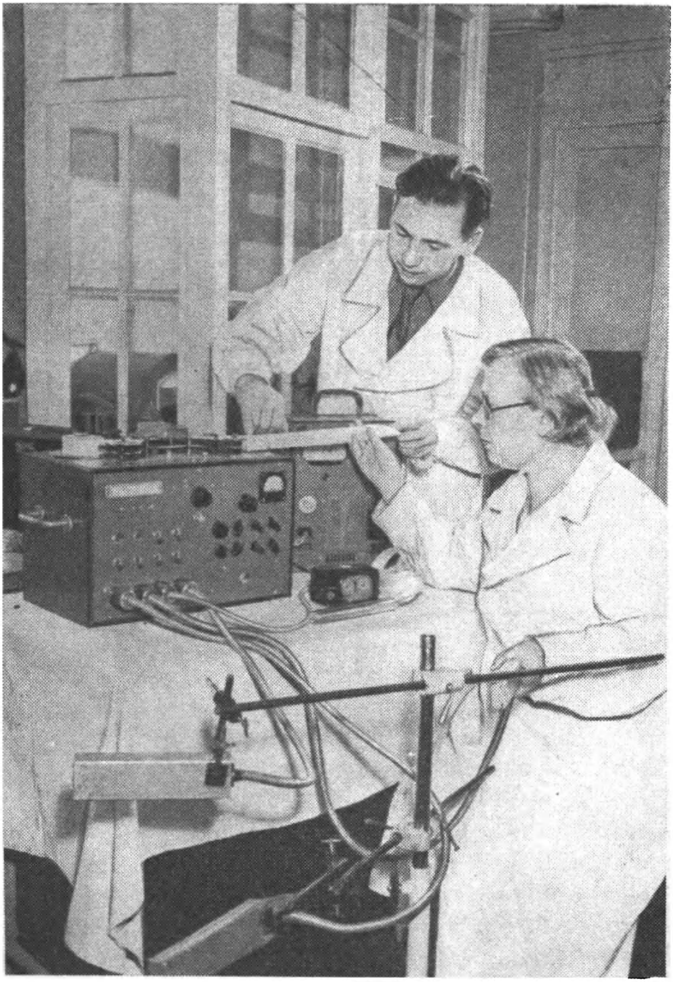
"The time is not far off when man will have at his disposal atomic energy—a source that will enable him to build the life that he desires," such were the prophetic

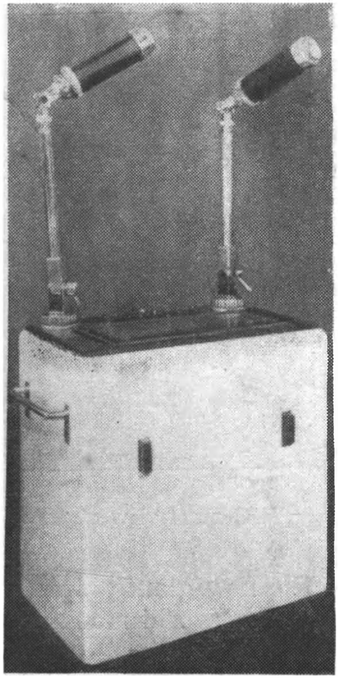


An apparatus with radioactive sodium designed to determine the speed of the blood flow

Examination of the thyroid-gland with the aid of radioactive iodine

words pronounced some forty years ago by the eminent Russian scientist V. I. Vernadsky.

We have told only a small part of what radioactive isotopes are doing for us today. The extensive peaceful use of atomic nuclei will in the future lead to a broad-scale revision of technological methods. Mankind stands on the threshold of a new scientific, technical and industrial revolution, a revolution that will far outstrip the industrial revolutions of steam and electricity.



Universal radiograph

The atom has not yet revealed all its secrets to man. Much within it is unknown, and many of its titanic forces are still unharnessed. The task of present-day science is to get at these forces and to make them serve the peaceful transformation of the earth.

Hundreds of Soviet investigators using powerful machines are storming the invisible bastions of the microcosmos. In April 1957 the Soviet Union put into operation the most powerful accelerator in the world. It permits physicists to bombard atoms and probe their depths. The "heart" of this machine, a proton synchrotron, is a 36,000-ton electromagnet with an outside diameter exceeding 70 metres. The protons during their period of acceleration cover in 3.3 seconds a distance of approximately 900,000 kilometres, which is greater than that from the earth to the moon and back again.

General view of the Joint Nuclear Research Institute

The new giant "atom smasher" which will undoubtedly bring the world many new and important discoveries, has been presented by the Soviet Government to the Joint Nuclear Research Institute. The Soviet Union has armed an international body of scientists with the latest in engineering science for the solution of nuclear physics problems.

The task now confronting the entire world is to make impossible the use of atomic energy—this great discovery of the human mind—for purposes of mass extermination of human beings and the destruction of cities, centres of industry, and of culture and science. This great scientific achievement that has opened up a new era in the history of mankind can and must ensure the people of the earth a radiant life.